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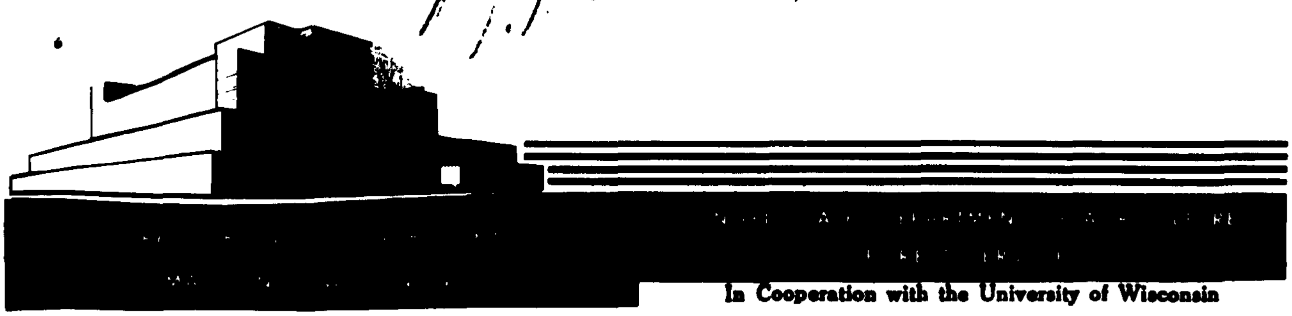

In Cooperation with the University of Wisconsin

EFFECT OF TEMPERATURE AND RESTRAINT DURING DRYING ON THE TENSILE PROPERTIES OF HANDSHEETS

By

VANCE C. SETTERHOLM, Forest Products Technologist
and
WARREN A. CHILSON, Chemical Engineer

Forest Products Laboratory,[1] Forest Service
U.S. Department of Agriculture

and
A. T. LUEY, Manager
Boxboard Research and Development Association

Summary

Handsheets prepared from a bleached southern pine kraft pulp were dried at 73°, 150°, and 220° F. under four degrees of restraint. Analysis of stress-strain data from tension tests revealed that increasing either drying temperature or restraint during drying increased the tensile properties, and that restraint had the greater effect on modulus of elasticity, tensile strength, and stretch.

Introduction

Studies conducted in 1959[2] at the Forest Products Laboratory showed that the bending stiffness of multiple-ply handsheet paperboards can be predicted from a knowledge of the thickness and modulus of elasticity for each of the individual plies. When an attempt was made to predict the stiffness of commercial cylinder board by using data from thickness and tension tests on individual plies that had been separated by soaking in water and subsequently dried, the calculated values were consistently lower than stiffness values obtained from bending tests on samples of board that had not been soaked.

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[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2]Work in cooperation with the Boxboard Research and Development Association, Kalamazoo, Michigan.

This may have occurred because the soaking of the board for ply separation lowered the modulus of elasticity of the plies and that subsequent drying did not restore this property.

It was apparent that the methods used during the drying were different. The machine-made board had been dried at a high temperature and under tension in the machine direction, and the soaked plies had been redried at a lower temperature without any tension being applied. If tension and drying temperature affected the bending stiffness, knowledge of the extent of this effect would be a valuable contribution to the manufacture of both Fourdrinier and cylinder papers and paperboards.

A preliminary study was therefore undertaken in 1959 on handsheets to determine the effect of different drying temperatures and various degrees of restraint on the tensile properties of paper.

Materials, Apparatus, and Test Methods

A bleached southern pine sulfate pulp of the type that is often used as the top liner in a cylinder board was processed to a freeness of 450 milliliters (Canadian Standard) in a Laboratory beater. Handsheets weighing about 3 grams or 15 pounds per 1,000 square feet were made in a 7- by 9-inch sheet mold. Each handsheet was pressed between blotters and rapidly ironed dry along a 1/2-inch-wide strip at the narrow end while it was still supported on the blotters.

The wet sheets with dry edges were carefully placed in a specially designed restraining apparatus shown in figure 1. This apparatus was essentially two rigidly supported bar clamps, with one of the clamps supported by a machine screw with a crank attached, so that the distance between the two clamps could be accurately controlled. The other clamp was pinned only at the center, so that it could turn to compensate for any unevenness in the sheet as it dried. A supporting plate, not shown in figure 1, was used to position the sheet between the clamps. It was removed as soon as the sheet was clamped in place.

Handsheets were dried in the apparatus at temperatures of 75°, 150°, and 220° F. under four degrees of restraint. This was accomplished by drying with the clamps separated by a distance equal to the length of the wet sheet and reducing the distance between clamps by 0, 2, 4, and 6 percent by turning the crank. Thus, the minimum restraint allowed for 6 percent shrinkage, and this amount was determined from measurements on pulp sheets dried completely free of restraint.

Three 7- by 9-inch sheets were made for each condition of test. Restraint was applied in the long dimension of the sheet. Since clamping was along two edges only, the finished sheet, when dry, had its narrowest width at the center, its appearance being somewhat saddle shaped. Thus it was apparent that the stresses varied across the sheet. Consequently, only two 3/4-inch-wide test specimens were taken for the tests from the center of each sheet.

Tension tests were made on specimens using an Instron machine to measure loads. A special-type paper extensometer was used to measure strains. From load strain curves, the physical properties, tensile strength, stress at proportional limit, modulus of elasticity, and strain at failure were determined.

Results and Discussion

The average properties for handsheets dried at temperatures of 75°, 150°, and 220° F., with restraint that allowed for 0, 2, 4, and 6 percent shrinkage, are shown in table 1 and figure 2. These data (fig. 2-A) show that increasing the restraint increased the modulus of elasticity.

In each case the modulus of elasticity was approximately doubled in going from the unrestrained (6 percent allowance for shrinkage) to the maximum restrained drying condition (no allowance for shrinkage). For example, the modulus of elasticity for handsheets dried at 75° F. increased from 306,000 to 683,000 pounds per square inch. Increasing the temperature of drying from 75° to 220° F. increased the modulus of elasticity from 25 to 60 percent, depending on the amount of restraint applied. By far the greatest effects of temperature on increasing the modulus of elasticity appeared to be in the temperature range from 75° to 150° F. The data were too scattered to clearly establish the effect of increasing the drying temperatures from 150° to 220° F.

The effect of restraint and temperature during drying on tensile strength (fig. 2-C) parallels that of the effect on modulus, but to a lesser extent. At 75° F., for example, increasing restraint from a minimum to maximum amount increased strength about 53 percent, or from 3,370 to 5,170 pounds per square inch, but at 220° F. the increase in strength, due to restraint during drying, was only about 22 percent. Higher temperatures during drying increased the strength of handsheets, but the scatter of data made it difficult to specify the exact extent to which the handsheets were affected.

The increases in strength and modulus of elasticity were accomplished at a sacrifice of stretch as shown in figure 2-D. As the restraint and temperature increased, the strain at failure decreased. For example, at 75° F. the stretch was reduced from a value of 6.4 to 3.2 percent.

The effect of temperature and restraint on the stress at proportional limit is shown in figure 2-B. Here it can be seen that the effects of temperature and restraint on this stress were similar to the effects on strength and modulus of elasticity.

Table 1.--Tensile properties of handsheets dried at various temperatures and degrees of restraint

Temperature	Allowance for shrinkage	Stress at proportional limit	Strength	Modulus of elasticity	Strain at failure
°F.	Pct.	P.s.i.	P.s.i.	P.s.i.	Pct.
73	6	990	3,370	306,000	6.44
73	4	900	3,380	244,000	7.17
73	2	1,200	4,890	502,000	4.76
73	0	1,710	5,170	683,000	3.19
150	6	1,105	4,010	409,000	5.54
150	4	1,450	4,300	548,000	3.52
150	2	2,000	5,540	835,000	2.36
150	0	2,040	5,290	807,000	1.70
220	6	1,280	4,070	485,000	4.32
220	4	1,580	4,130	513,000	3.20
220	2	1,790	4,730	793,000	2.29
220	0	1,915	4,980	862,000	1.81

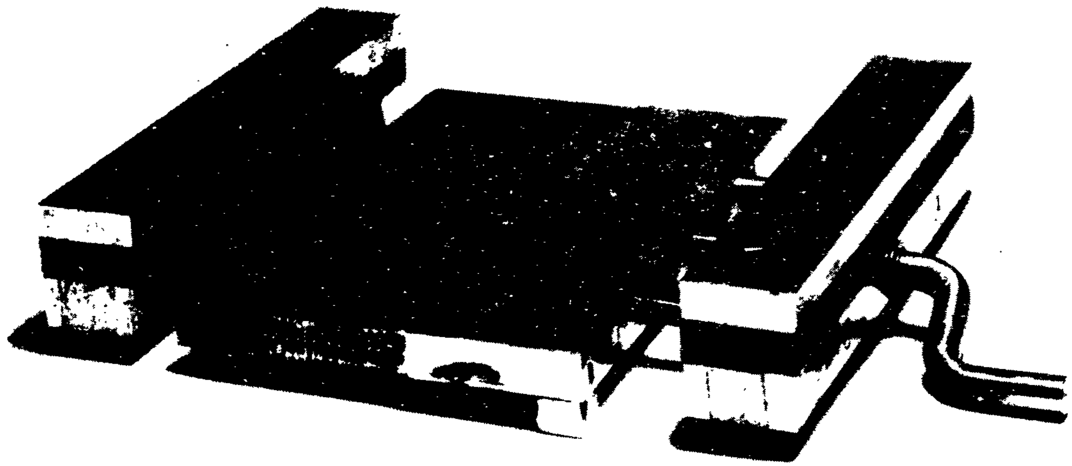

Figure 1.--Apparatus used to restrain handsheet during drying. The handsheet is inserted beneath the top plate of each clamp.

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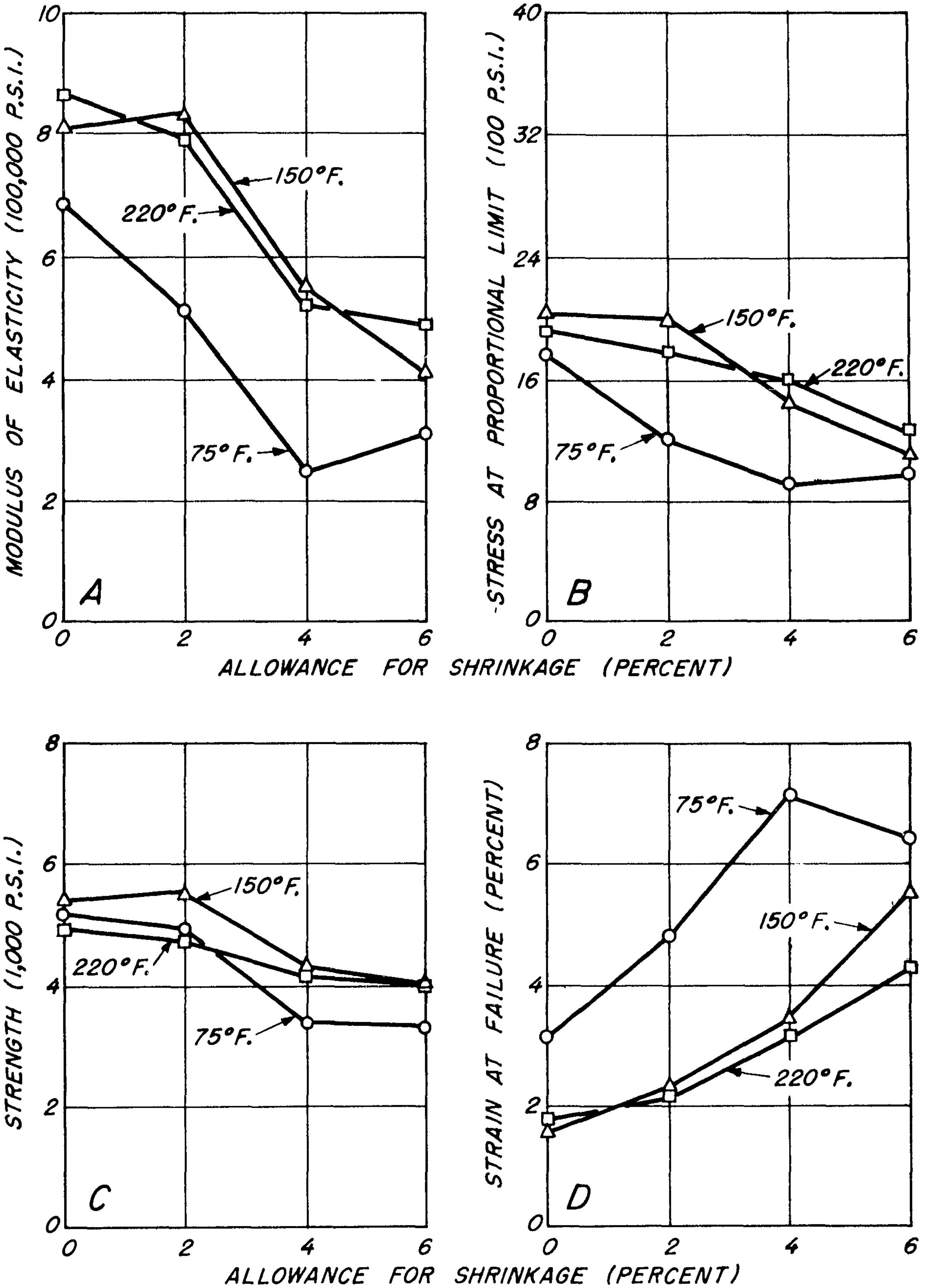

Figure 2. --Average properties of handsheets dried at various temperatures and restraints.

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